File Revision Date:
November 12th, 2024

Data Set Description:

PI:	Dr. Gerald Nedoluha
Instrument:	22 GHz ground-based microwave instruments
Site(s):	Lauder, New Zealand Mauna Loa, Hawaii Table Mountain, California
Measurement Quantities:	Water vapor profile

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DOI: At this time, no DOIs have been assigned to any of the WVMS datasets housed in NDACC. However, data license type would be expected to be CC-0 (most open).

Reference Articles:

Nedoluha, G. E., et al. (2024), The Spread of the Hunga Tonga H_2O Plume in the Middle Atmosphere Over the First Two Years Since Eruption, Journal of Geophysical Research: Atmospheres, 129, e2024JD040907. https://doi.org/10.1029/2024JD040907

Nedoluha, G. E., Gomez, R. M., Boyd, I., Neal, H., Allen, D. R., Lambert, A., & Livesey, N. J. (2023), Measurements of stratospheric water vapor at Mauna Loa and the effect of the Hunga Tonga eruption. Journal of Geophysical Research: Atmospheres, 128, e2022JD038100. https://doi.org/10.1029/2022JD038100. March 2023.

Nedoluha, Gerald E., R. Michael Gomez, Ian Boyd, Helen Neal, Douglas R. Allen, David Siskind, Alyn Lambert, and Nathaniel J. Livesey (2022), Measurements of Mesospheric Water Vapor from 1992 to 2021 at three stations from the Network for the Detection of Atmospheric Composition Change, J. Geophys. Res., Atmospheres, 127, e2022JD037227. https://doi.org/10.1029/2022JD037227, October 2022.

Sauvageat, E., R. Albers, M. Kotiranta, K. Hocke, R. M. Gomez, G. Nedoluha, and A. Murk (2021), Comparison of three high resolution real-time spectrometers for microwave ozone profiling instruments, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, doi:10.1109/JSTARS.2021.3114446, Oct. 2021.

Nedoluha, G. E., Kiefer, M., Lossow, S., Gomez, R. M., Kämpfer, N., Lainer, M., Forkman, P., Christensen, O. M., Oh, J. J., Hartogh, P., Anderson, J., Bramstedt, K., Dinelli, B. M., Garcia-Comas, M., Hervig, M., Murtagh, D., Raspollini, P., Read, W. G., Rosenlof, K., Stiller, G. P., and Walker, K. A., The SPARC water vapor assessment II: intercomparison of satellite and ground-based microwave measurements, Atmos. Chem. Phys. 17, 14543–14558, 2017.

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Gomez, R. M., Nedoluha, G. E., Neal, H., McDermid, I. S., The fourth-generation Water Vapor Millimeter-Wave Spectrometer, Radio Sci., 47, RS1010, doi:10.1029/2011RS004778, 2012.

Nedoluha, Gerald E., Bevilacqua, Richard M., Gomez, R. Michael, Waltman, William B., Hicks, Brian C., Thacker, D. L., and Matthews, W. Andrew, Seasonal Variation of Middle Atmospheric Water Vapor, J. Geophys. Res., October, 1996.

Lahoz, W. A., M. R. Suttie, L. Froidevaux, R. S. Harwood, C. L. Lau, T. A. Lungu, G. E. Peckham, H. C. Pumphrey, W. G. Read, Z. Shippony, R. A. Suttie, J. W. Waters, G. E. Nedoluha, S. J. Oltmans, J. M. Russell III, and W. A. Traub, Validation of UARS microwave limb sounder 183 GHz H2O measurements, J. Geophys. Res., 101, 10129-10149, 1996.

Harries, J. E., J. M. Russell III, A. F. Tuck, L. L. Gordely, P. Purcell, K. Stone, R. M. Bevilacqua, M. Gunson, G. Nedoluha, and W. A. Traub,, Validation of Measurements of Water Vapour from the Halogen Occultaion Experiment (HALOE), J. Geophys. Res., 101, 10205-10216, 1996.

Nedoluha, Gerald E., Richard M. Bevilacqua, R. Michael, Gomez, D. L. Thacker, William B. Waltman, and Thomas A Pauls, Ground-Based Measurements of Water Vapor in the Middle Atmosphere, J. Geophys. Res., 100, 2927, 1995.

Thacker, D. L., Bevilacqua, R. M., Waltman, W. B., Pauls, T. A., Gomez, R. M, Nedoluha, G. E., and Schwartz, P. R., 1995 Ground-based Sensing of Water Vapor in the Stratosphere and Mesosphere, IEEE trans. on inst. and meas., 44(2), 355.

<u>Instrument Description:</u>
The instrument is a microwave spectrometer observing atmospheric thermal emission at 22 GHz from the ground. The original instrumentation consisted of a cryogenic heterodyne receiver and multi-channel filterbank spectrometer. While there have been many incremental updates to the systems, the main changes to the new systems, which were introduced between 2008 and 2011, were the transitions

to room temperature receivers and FFT spectrometers (Gomez et al., 2012). WVMS1, WVMS2 and WVMS3 used filterbank spectrometers, while WVMS4, WVMS5, WVMS6 and WVMS7 backends originally consisted of AC240 FFT spectrometers (4^{th} Gen.) with 16384 channels over a 500 MHz bandwidth, which have been incrementally updated to U5303A FFT spectrometers (5^{th} Gen.) which make use of the first 8192 channels only over a 500 MHz bandwidth.

The spectrometers record the spectral lineshape of a water vapor rotational transition every 20 minutes at about 20 degrees elevation. Observations continue 24 hours a day whenever weather permits. A water vapor mixing ratio profile as a function of pressure can be retrieved from the water vapor spectra obtained.

<u>Algorithm Description:</u>
The standard WVMS measurement product (with version keyword name "weekly.2021") consists of a water vapor mixing ratio profile (ppmv) from 40-80 km (Nedoluha et al., 2022). It is retrieved using an optimal estimation retrieval method based on Rodgers (Rev. Geophys. 14, 608, 1976) from a ∼1 week integration of the spectrum within ±30 MHz of the H2O emission peak at 22 GHz.

Special processing of the Mauna Loa WVMS measurements to study the effects of the Hunga eruption into the stratosphere (Nedoluha et al., 2023) included retrievals that made use of a wider ±160 MHz spectral measurement centered around the H2O emission peak with a much shorter integration period. Measurements submitted to NDACC are differentiated from the standard weekly retrievals by inclusion of the version name keywords "gn2022.strato".

The AC240 spectrometers have a documented bias (Sauvageat et al., 2021), which we also determined independently through comparisons with MLS. For these measurements, it was found that an increase of the WVMS measured brightness temperatures of 7% removed this change in bias between WVMS and MLS. This correction has been applied to the processing of all measurements using this spectrometer submitted to NDACC.

L0/L1: L0 measurements, consisting of the raw data collected by the instrument logging program, are housed on the Bryan Scientific Consulting LLC server 'Zenith', at NRL and locally on each machine.

<u>Expected Precision/Accuracy of Instrument:</u>
Both the precision and accuracy are ~7% for most of the data. The total measurement error (assuming the terms add in quadrature) is therefore ~10%.
The measurement error is somewhat smaller for more recent measurements, and somewhat larger for the earliest measurements.
The 1992 Table Mountain measurements show smaller mixing ratios than subsequent measurements and have a calibration uncertainty of ~10%.
WVMS2 measurements from 1994 to the present, and all WVMS3 measurements are made with an additional set of 50 kHz filters, and therefore should have better high altitude retrievals

<u>Instrument History:</u>

- Measurements are available from Lauder, New Zealand, from 1992-present. The original WVMS1 instrument was replaced with WVMS7 (4th Gen.) from October 28th, 2011 using the AC240 spectrometer. WVMS7 was further upgraded to 5th Gen. on March 28th, 2024 using the U5303A spectrometer.

- Measurements are available from Mauna Loa, Hawaii, from 1996-present. The original WVMS3 instrument was replaced with WVMS6 (4th Gen.) from March 7th, 2011 using the AC240 spectrometer. This was further upgraded to 5th Gen. on November 2nd, 2021 using the U5303A spectrometer.

  The Mauna Loa volcanic eruption on November 28th, 2022 led to loss of power and access to the observatory. Solar panels were installed on the microwave building on September 5th, 2023 and WVMS5 (5th Gen.) became the primary measuring instrument from September 26th, 2023 due to instrumental issues with WVMS6 (which have since been fixed).

- Measurements are available from Table Mountain, California, with WVMS2 from 1993-1997, and with WVMS4 (4th Gen.) since July 3rd, 2008. This was further upgraded to 5th Gen. on April 17th, 2019 using the U5303A spectrometer.

The major changes in instrumentation are described in Gomez et al., 2012.